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US 4389846 A **US 4160365 A** **US 3961199 A**

(58) Field of Search
UK CL (Edition N) **F1B**
INT CL^{6} **F02B 37/04 37/12 37/14**

(54) **Turbocharged internal combustion engine arrangement**

(57) A turbocharger 2, 3 internal combustion engine (40) is provided with a combustion chamber 7 to provide extra exhaust gas to drive the turbine 2. The turbocharger is coupled to a motor/generator 4 which can be used as a motor for starting and as a generator during normal running. A turbine 20 downstream of the turbine 2 may assist drive of the motor/generator 4. A further turbocharger (23, 24, Fig. 4) may be flow connected in series with the turbocharger 2, 3 and the combustion chamber 7 and motor/generator 4 may be associated with another turbine/compressor unit (20, 30).

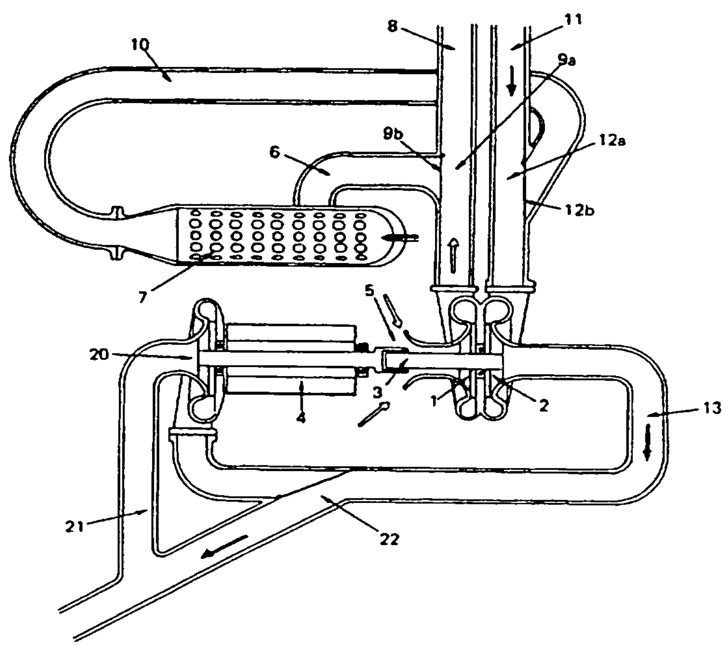

FIG. 3a

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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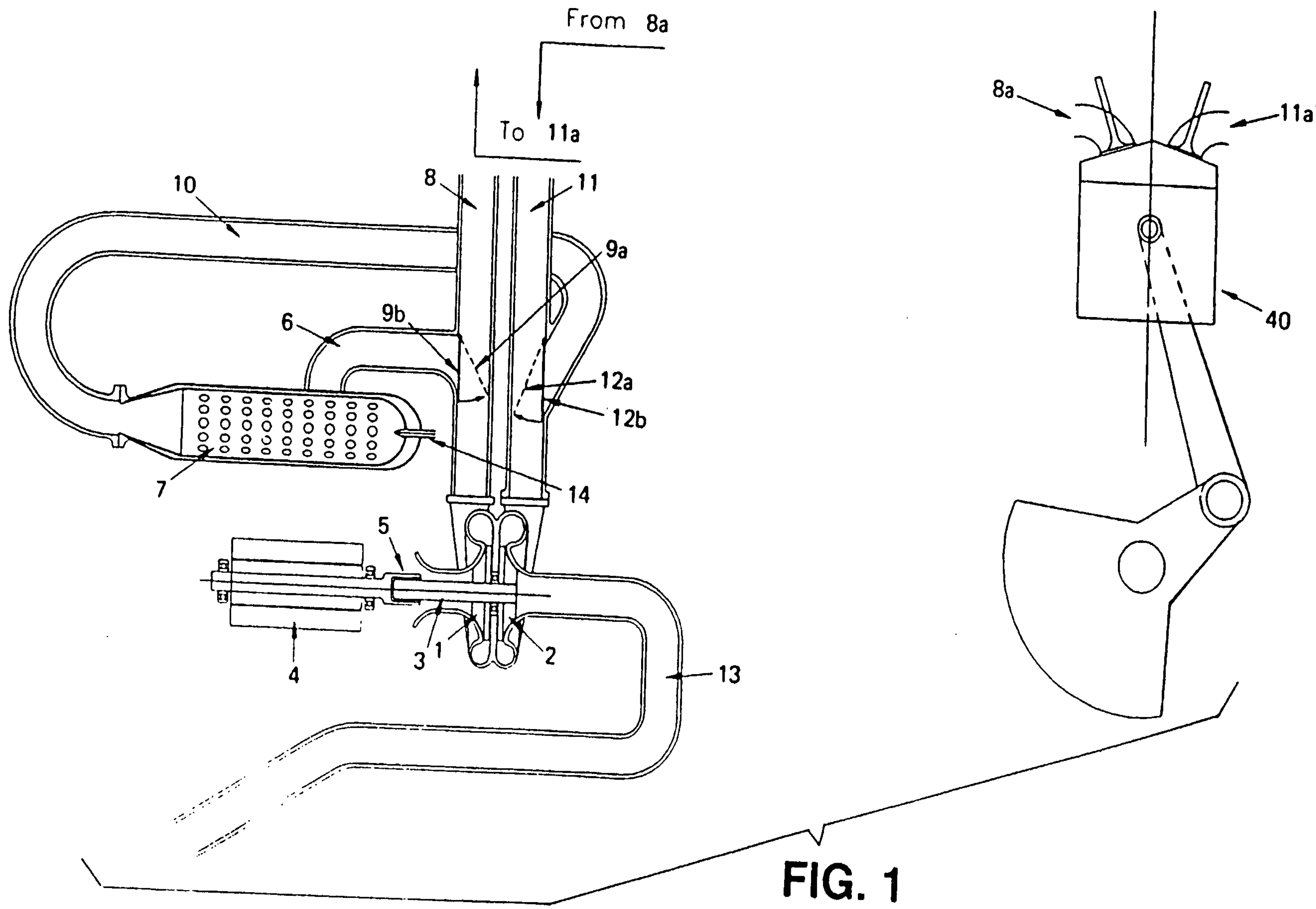

FIG. 1

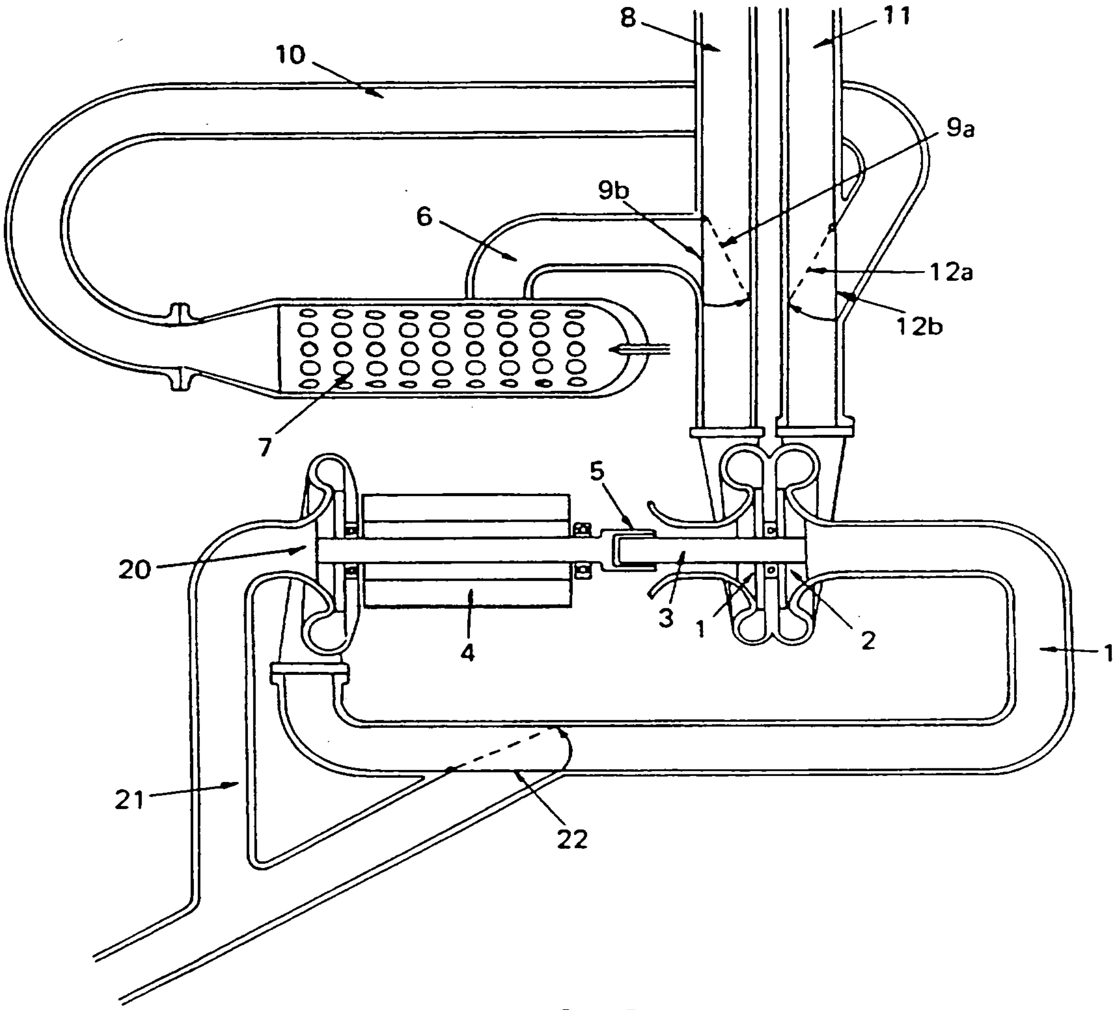

FIG. 2

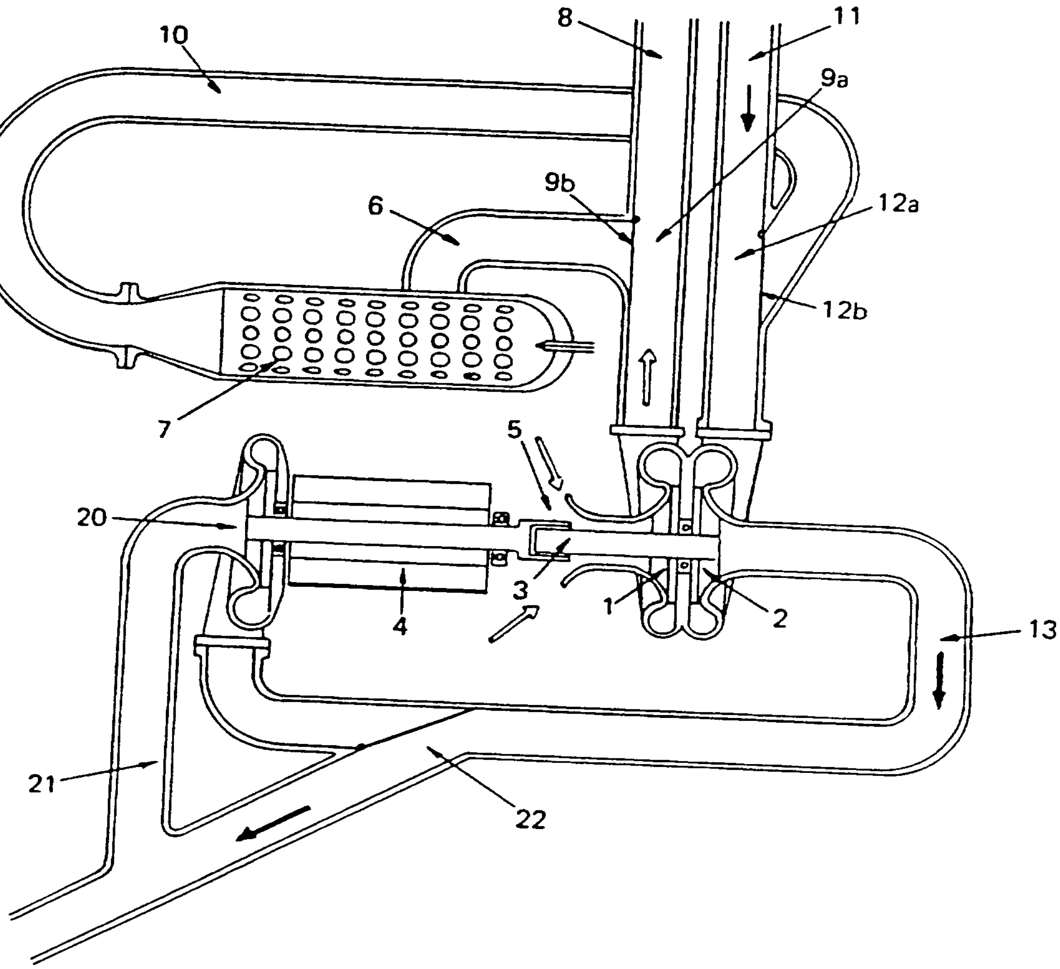

FIG. 3a

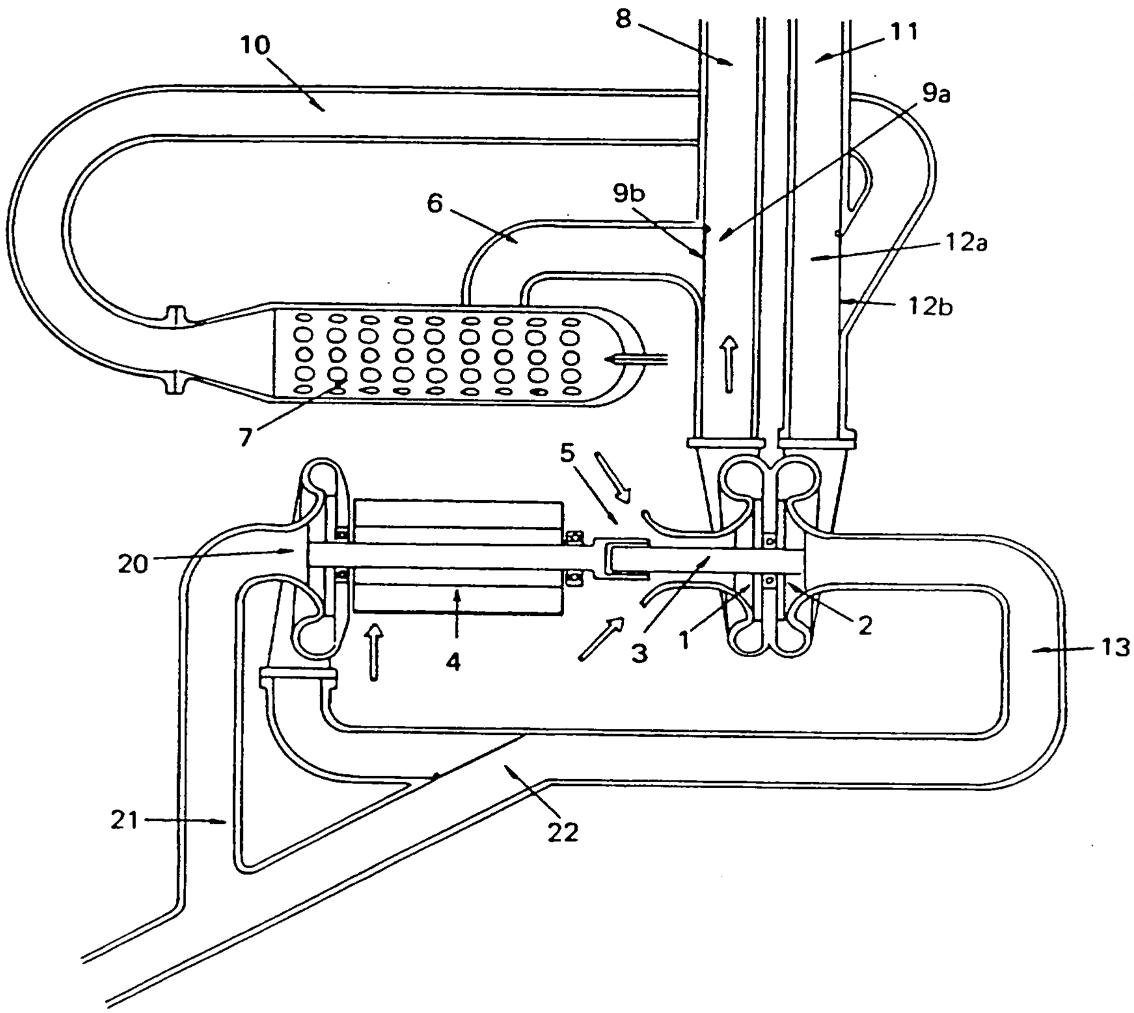

FIG. 3b

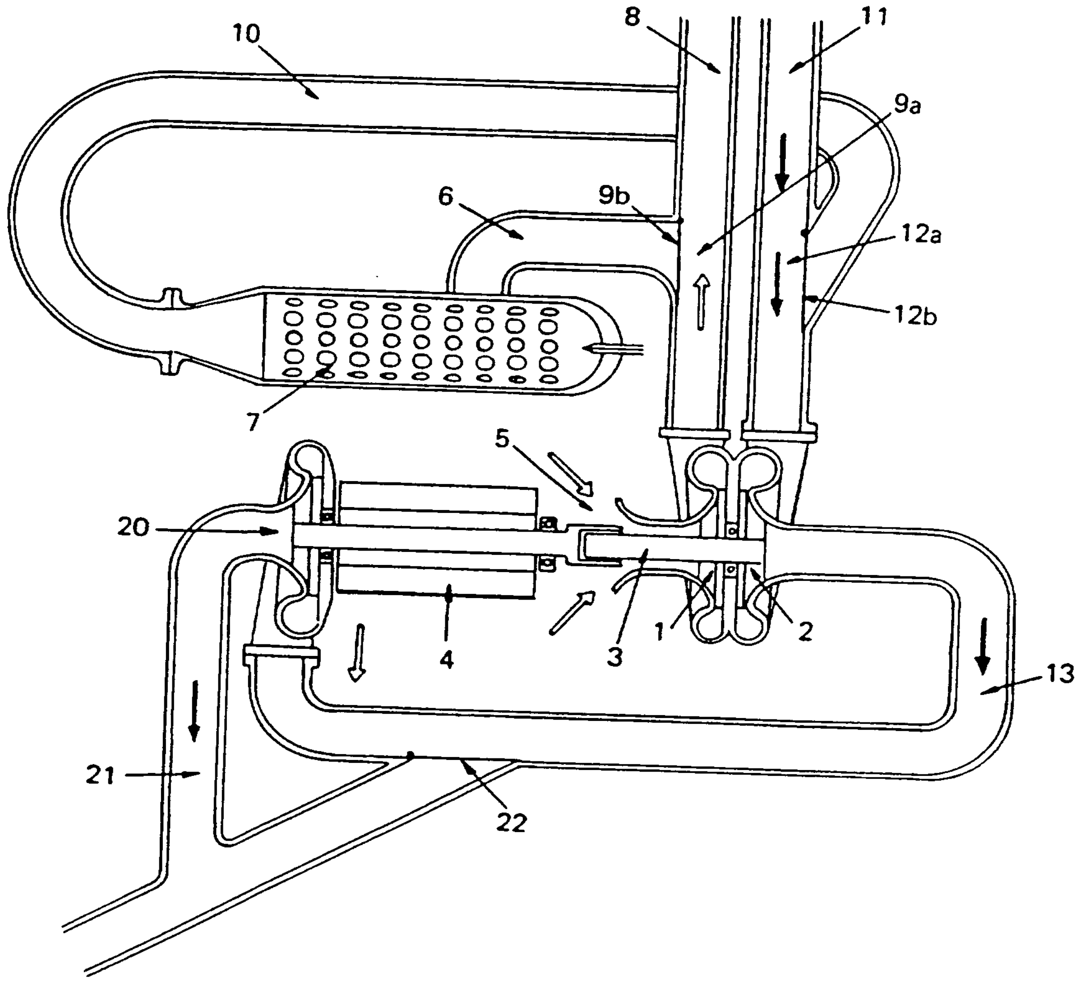

FIG. 3c

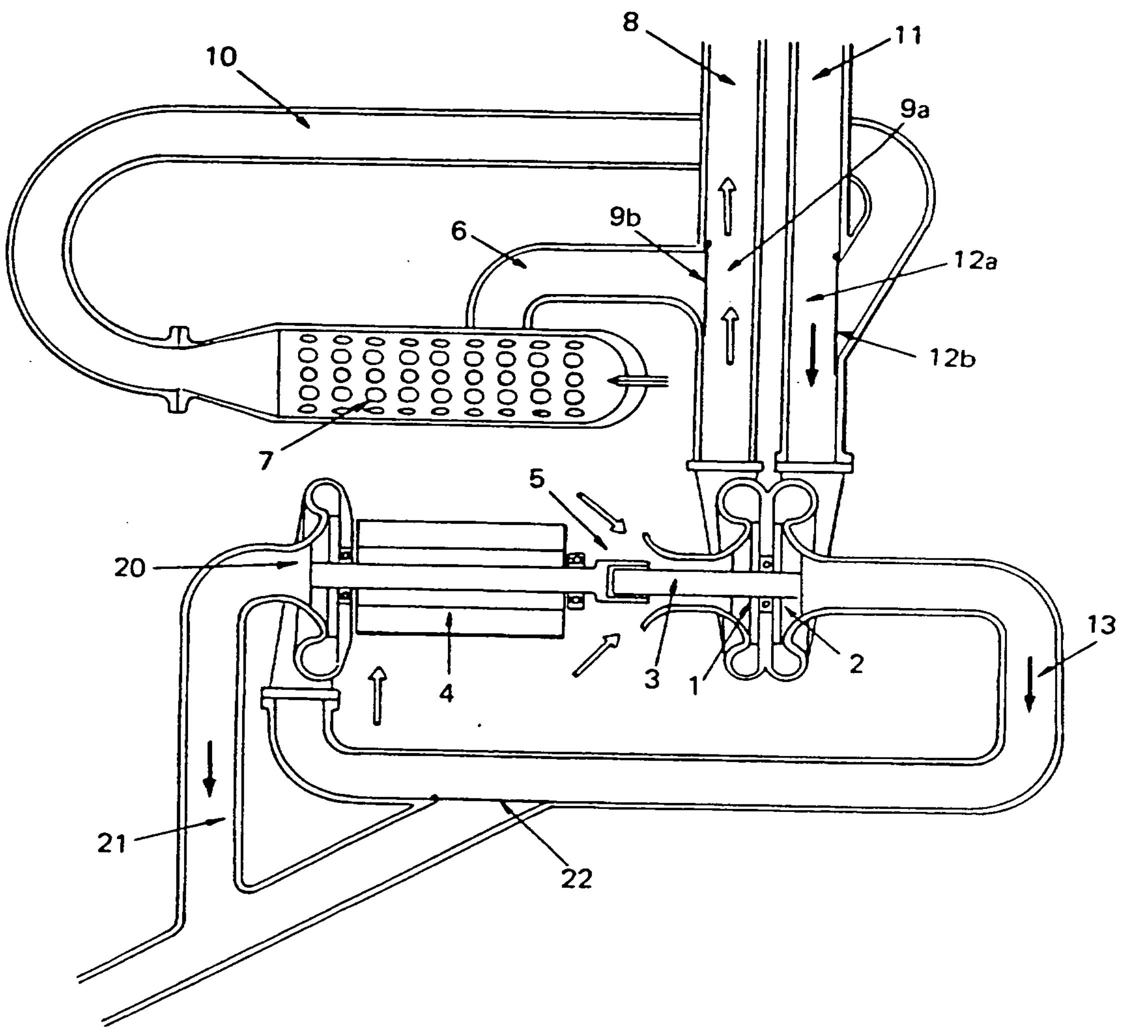

FIG. 3d

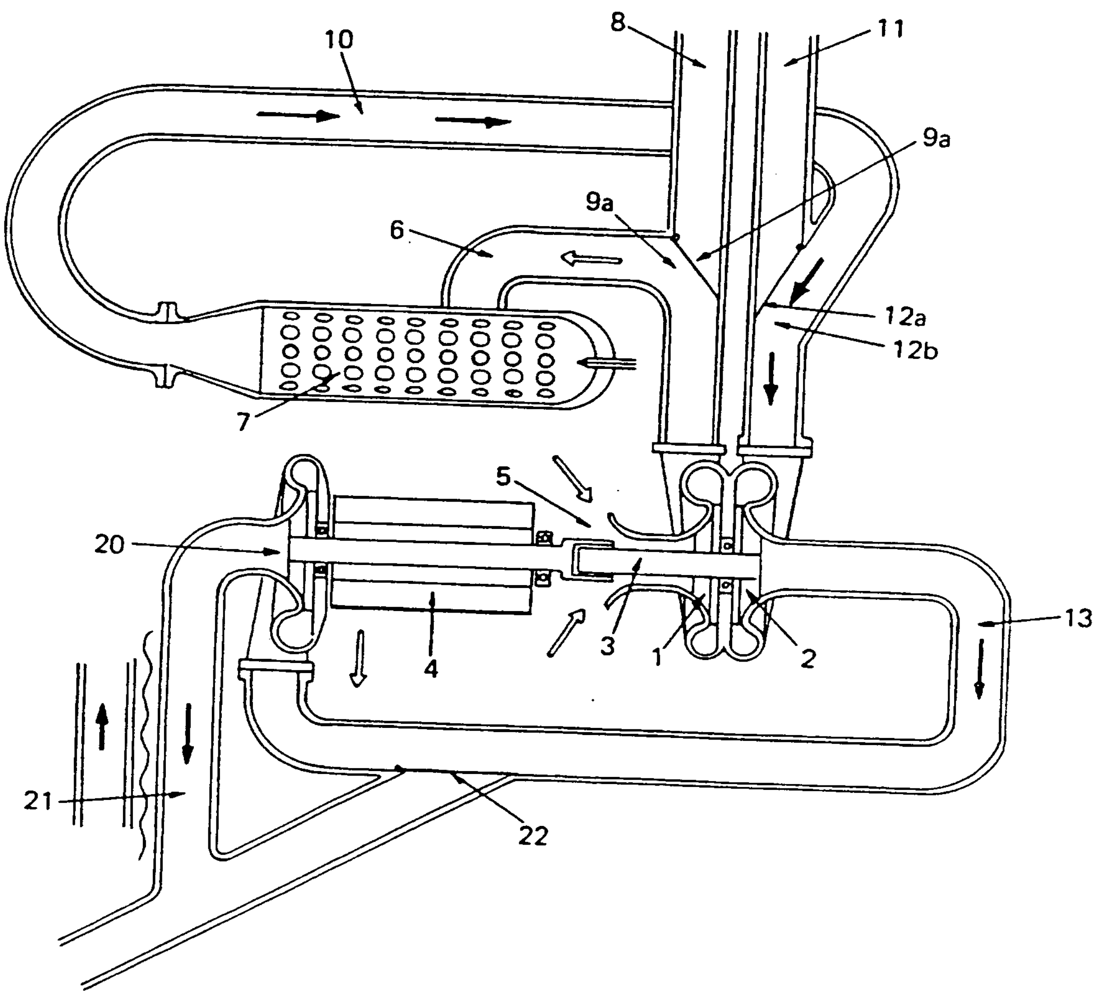

FIG. 3e

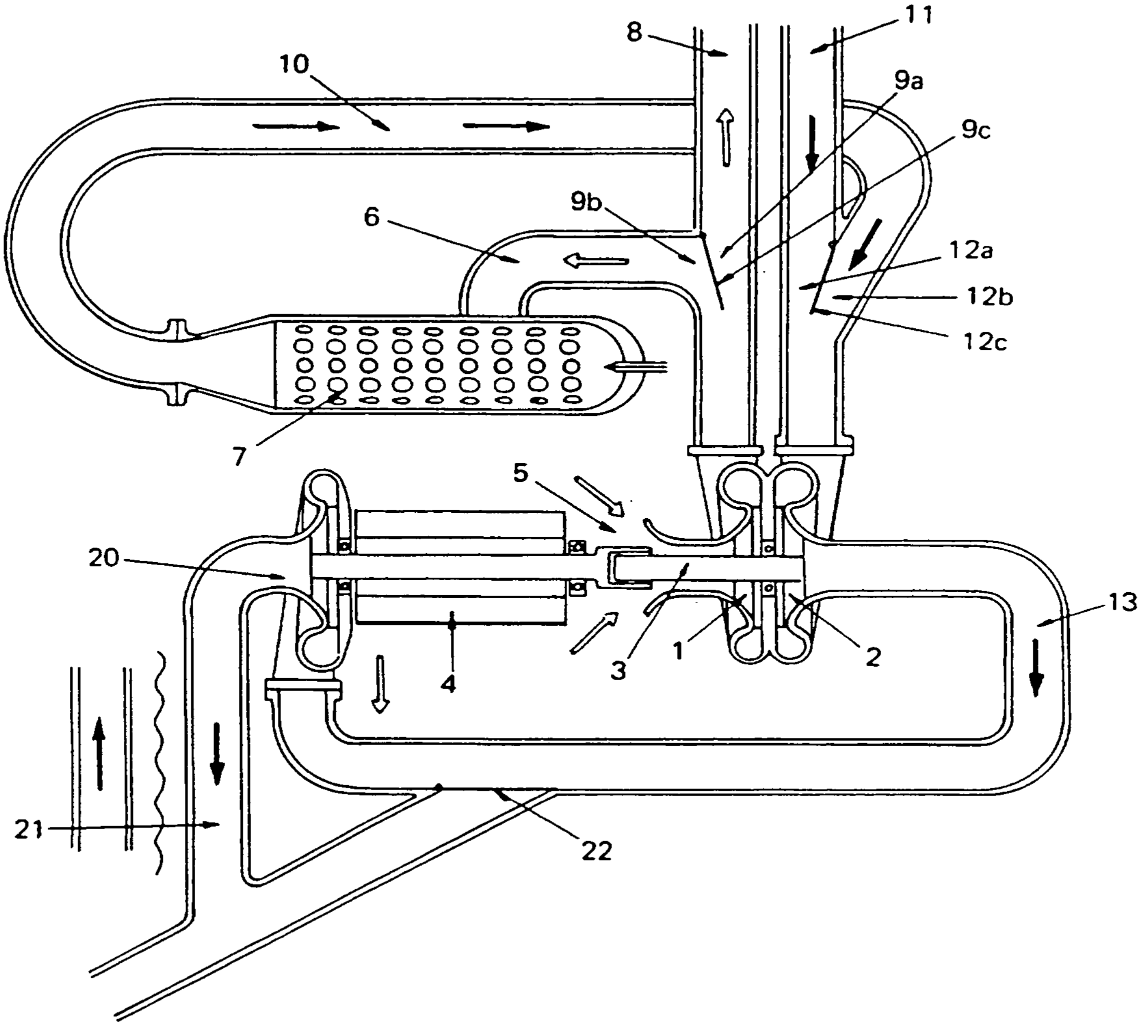

FIG. 3F

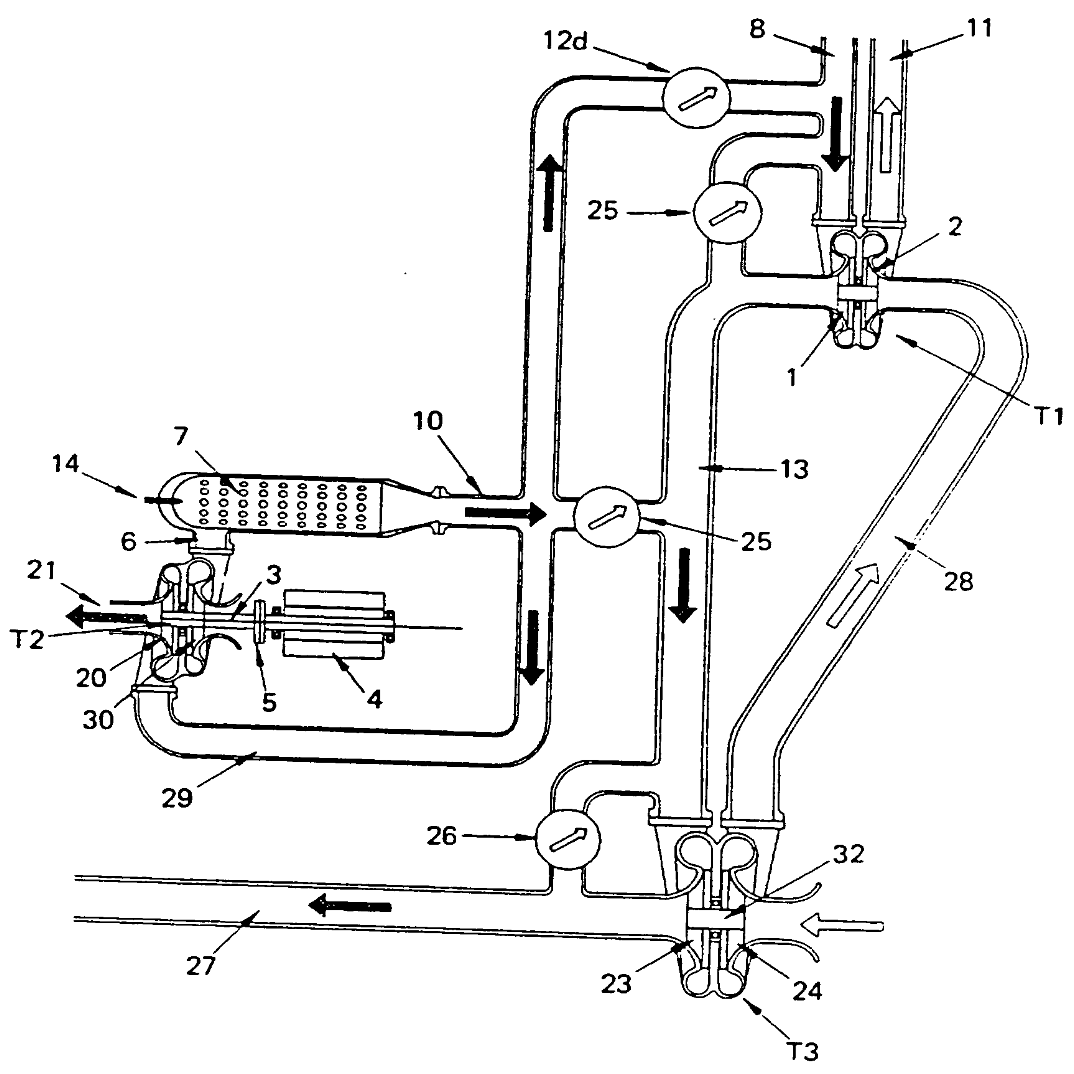

FIG. 4

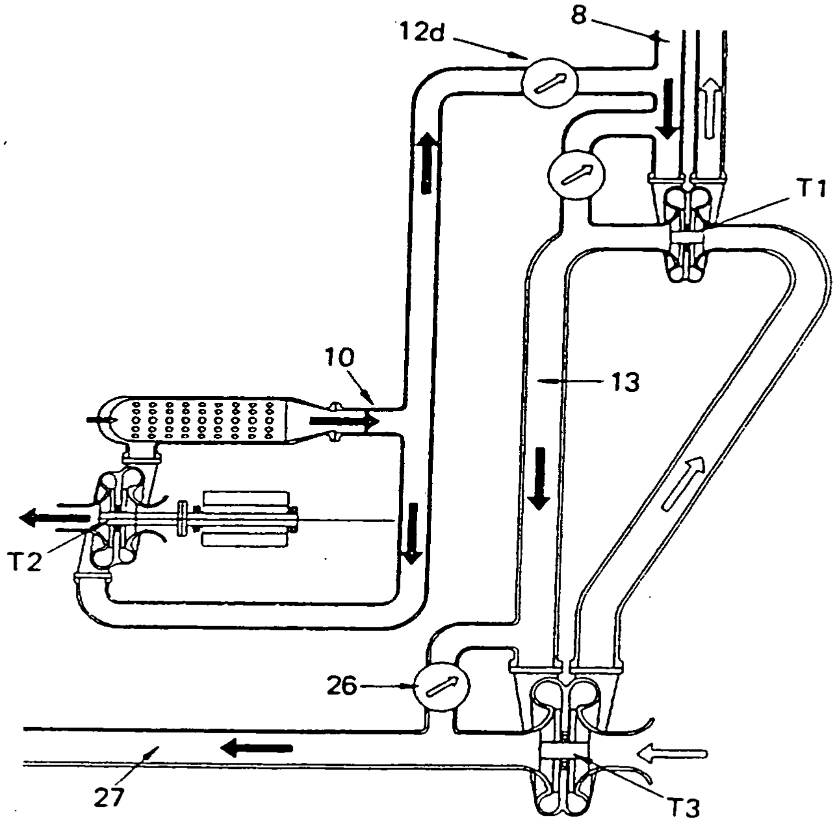

FIG. 4a

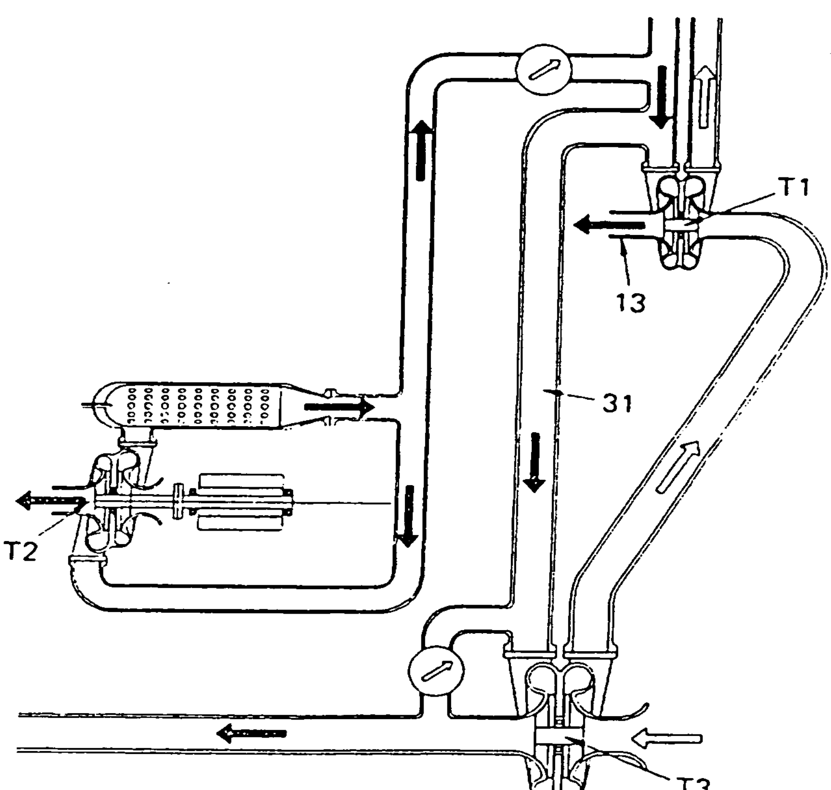

FIG. 4b

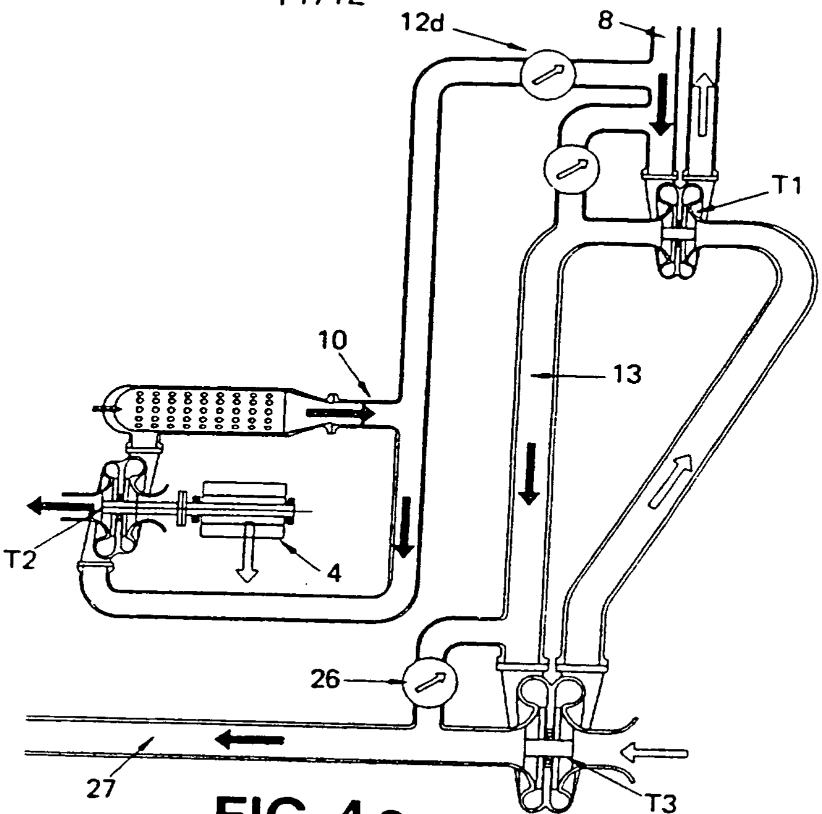

FIG. 4c

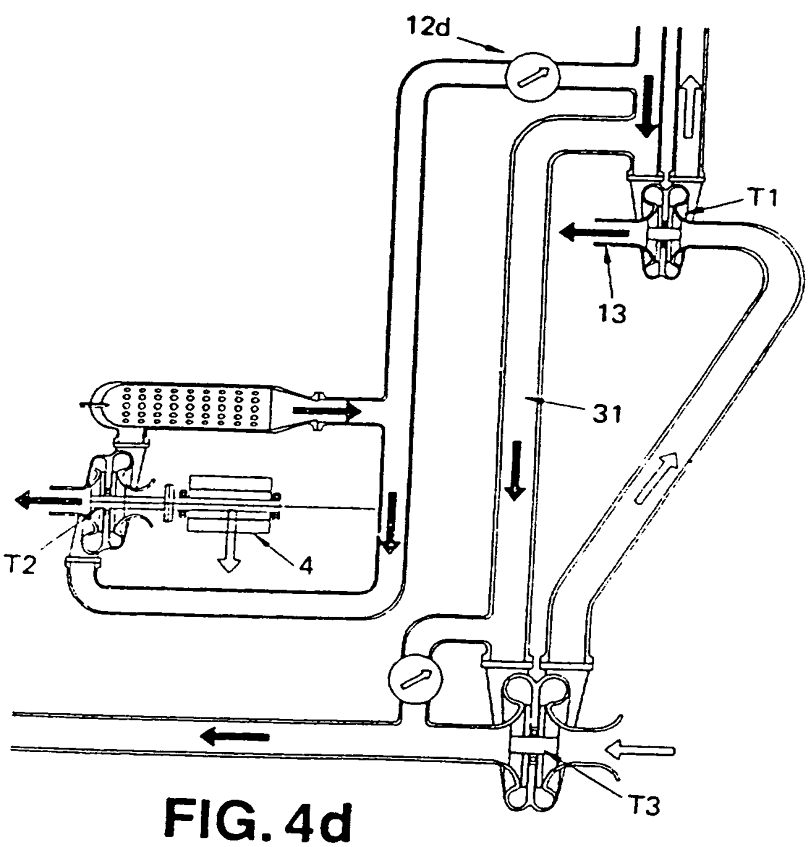

FIG. 4d

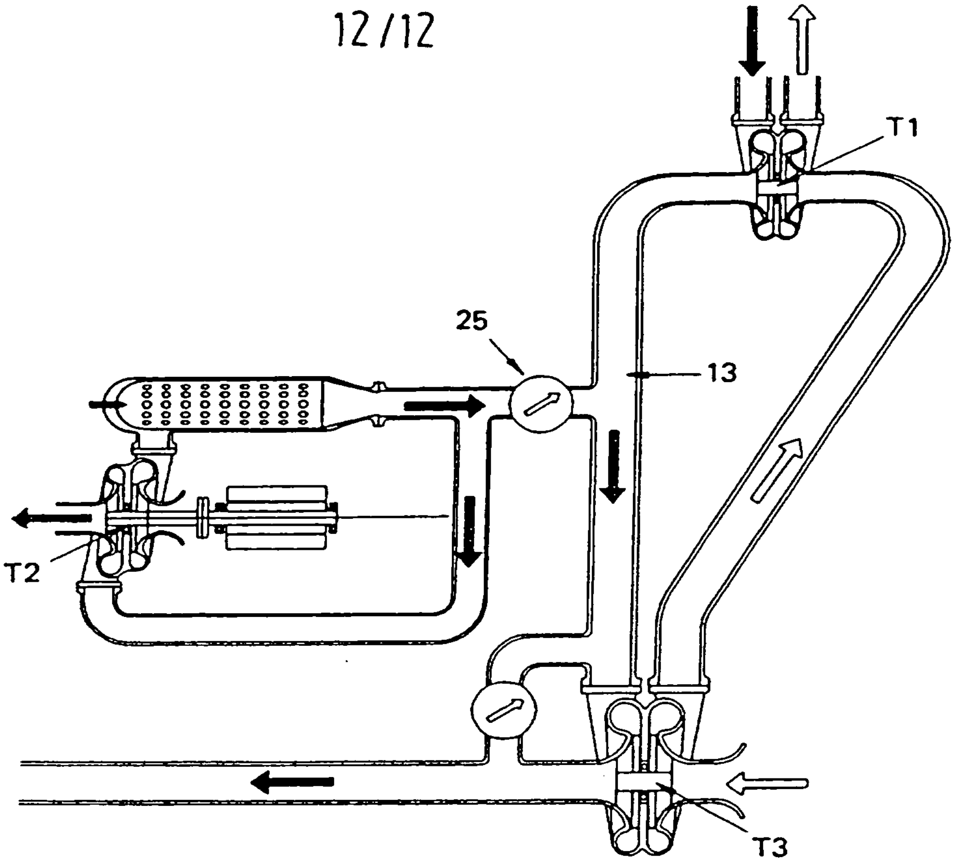

FIG. 4e

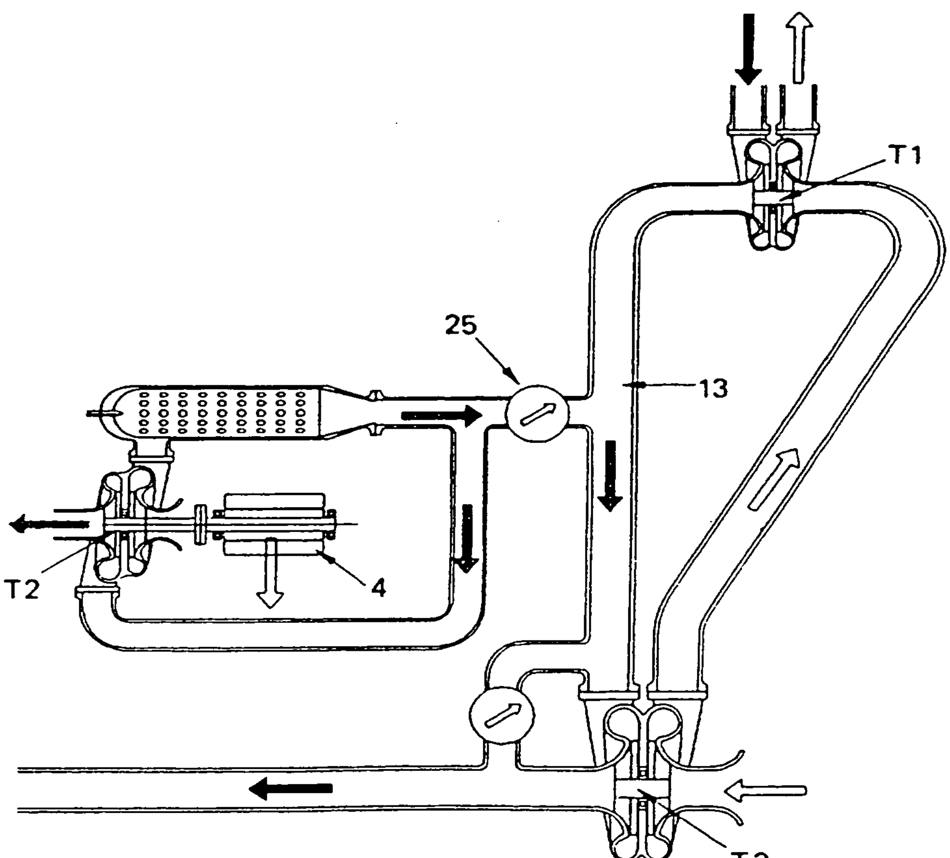

FIG. 4f

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Turbocharged Internal Combustion Engine Arrangement.

The invention relates to a turbocharged internal combustion engine arrangement, and preferably to a turbocharged diesel engine.

It is known that to compress the air going into an internal combustion engine will allow a greater fuel charge to be burnt which produces increased power. In the case of pressure charging by way of a turbocharger, the compressor is driven by a turbine which is driven by the exhaust gasses leaving the cylinders. Such systems have two operational problems:

- The rotational inertia of the turbine/compressor reduces the rate at which the engine can accelerate, this is known as turbo lag.
- When the engine is designed to give a very high performance through a high level of pressure charging, it will usually have a lower compression ratio to limit pressures and temperatures in the cylinder head. This introduces difficulties in starting, particularly in cold conditions.

In GB-A-1396082 published in 1975, there is proposed an internal combustion engine having an exhaust turbo charger, the engine including a further drive comprising a regulable electric motor which, in use maintains the rotary speed of the motor at a constant relationship with the engine over the entire operating speed of the engine.

It is one object of the invention to provide a turbocharged internal combustion engine adapted to provide extra power when required.

According to the invention in one aspect there is provided an internal combustion engine arrangement having a turbocharger comprising a turbine arranged to drive a compressor, characterised by an auxiliary combustion chamber and which is included in the turbocharger circuit.

Preferably the arrangement further comprises a rotary dynamoelectric machine coupled to the turbocharger.

Preferably the dynamoelectric machine is operable as a generator and the turbo is coupled via a clutch device. In this manner the arrangement can be freed of the inertia of the dynamoelectric machine and can operate as a conventional turbocharger.

When used as a generator operating whilst connected to the engine via the clutching device, energy can be withdrawn from the generator. In this form of the arrangement the level of energy withdrawn will be limited by the aerodynamic matching of the compressor and the turbine and typically will extract about 10% of the combustion power.

In a preferred embodiment supplementary means are provided to drive the generator. Preferably the supplementary means is a turbine arranged to operate in free turbine mode. The free turbine acts as a further expansion stage which can extract as much energy as its expansion ratio will allow from the extra energy left in the exhaust system after the turbocharger expansion stage. While the supplementary means may be connected to the electrical motor/generator in any way, it is advantageous to connect the free turbine to the dynamoelectric machine via a clutch device.

It is a much preferred feature of the invention that the electric motor/generator is a high speed, low inertia device capable of being directly driven by the turbine. Such a device would incorporate advanced permanent magnets and solid state switching.

In a further preferred embodiment, the generator and its associated turbocharger and including the auxiliary combustion chamber are operable as an auxiliary power unit independent of the main internal combustion engine. The auxiliary power unit can also be combined with a heat exchanger to extract heat from both its own and the main engine's exhaust system to improve efficiency.

It is also a feature of a preferred embodiment that compressed air bled from the compressor side can, after cooling through an ambient air heat exchanger, be expanded to ambient pressure to provide passenger compartment cooling or heating. In this configuration the power of the main internal combustion engine can be increased significantly by providing extra energy to the turbocharger directly from the device's combustion chamber. In such a configuration the incoming air must be divided between the auxiliary combustion chamber and the main internal combustion engine.

In a further preferred embodiment the auxiliary power unit is separated from the main internal combustion engine and does not share any aerodynamic devices with it.

In a further embodiment it is a more specific objective to increase the pressure of the ingoing charge to a turbocharged engine, preferably a turbocharged diesel engine.

In this embodiment a supplementary turbocharger is included in the circuit of the first mentioned turbocharger and auxiliary combustion chamber arrangement.

Preferably, the internal combustion engine has a main turbocharger circuit comprising a turbine and compressor; a combustion chamber; and a supplementary turbocharger circuit, the output of the supplementary circuit being arranged to supply pressurised air to the input side of the main turbocharger.

The extra power that can be developed in the above embodiment is limited only by the physical limitations imposed by the main internal combustion engine. Furthermore the design is much less constrained than is the case with an integrated design. In the case of a multi stage turbocharged engine it is found that by varying the amount of exhaust gases into the chambers between the internal combustion engine and the first turbocharger and the chamber between the turbochargers that great flexibility is found in determining the operating temperature and pressure regimes of the internal combustion engine.

Preferred embodiments can be used to pre-charge the inlet manifold of the internal combustion engine prior to start up, so overcoming the cold start difficulties experienced with low compression, high performance engines.

By providing valving to close the normal air entry passages of the inlet manifold of the internal combustion engine, it is also possible to introduce the exhaust gases from the auxiliary combustion chamber directly into the inlet manifold, since the air fuel ratio is such as to leave an excess of oxygen sufficient to start a diesel engine. Air can also be bled from the compressor stage for the same purpose. Under some circumstances the internal combustion engine can be started without the use of electric starting.

The preferred embodiments fall into two groups; namely those with the turbocharger circuit aerodynamic components are shared with the main engine; and free standing, in which the turbine of the turbocharger can operate independently.

In order that the invention may be well understood it will now be described by way of example with reference to the accompanying diagrammatic drawings wherein:

Figure 1 shows the basic circuit of an integrated turbocharger arrangement in accordance with the invention;

Figure 2 shows another integrated turbocharger arrangement in accordance with the invention;

Figures 3A to 3E shows the circuit of Figure 2 under different operating conditions;

Figure 4 shows a further embodiment in which turbine of the turbocharger can operate independently;

Figure 4b shows a variant of the Figure 4 embodiment;

Figure 4b shows a further variant of the Figure 4 embodiment;

Figure 4c shows a further variant of the Figure 4 embodiment;

Figure 4d shows a further variant of the Figure 4 embodiment;

Figure 4e shows a further variant of the Figure 4 embodiment; and

Figure 4f shows a further variant of the Figure 4 embodiment.

The same reference numerals are used to identify the same parts in the different embodiments.

The circuit shown in Figure 1 comprises a turbocharger which consists of a compressor 1 connected to a turbine 2 by a connecting shaft 3. A high speed, low inertia electric motor/generator 4 is connected by a clutch 5 to the shaft 3. The clutch 5 enables the motor to be connected or disconnected from the compressor 1. Clutch 5 may be a one way device.

A conduit 6 supplies pressurised air to a combustion chamber 7. An engine air intake circuit 8 branches off the conduit 6 and supplies pressurised air to the cylinders of a reciprocating internal combustion engine 40 via ports 8a (only one of which is shown) under control of a first director valve 9, which can be moved between positions 9a,9b and 9c at the inlet of the conduit 6.

A conduit 10 connects the outlet of the combustion chamber 7 and the engine exhaust conduit 11 supplying exhaust gases to the turbine 2 from port 11a of engine 40. A second set of director valve arrangement 12, moveable between positions 12a, 12b and 12c is present where the conduit 10 meets the conduit 11 (in a simplified device these valves may be omitted). The expanded exhaust gases exit to atmosphere via exhaust

conduit 13. A nozzle 14 extends from the fuel tank (not shown) through the wall of the combustion chamber 7 to inject fuel into the chamber 7 to provide extra exhaust gas energy when required.

In operation, air can be supplied to the compressor 1 and exhaust gas to the turbine 2 in the usual way. When the turbine 2 is in operation and the clutch 5 connects the motor 4 to the shaft 3, electricity will be generated and rectified by a rectifier (not shown) and may be stored in a battery. In this way the circuit can be used to generate and store electrical power. When the engine is running, the motor 4 may be used to supply auxiliary power, and this is especially useful when the engine is running at low power when there is insufficient energy in the exhaust gases to drive the turbine fast enough to pressurise the incoming air.

Motor/generator 4 is an A.C. machine and is provided with a conventional solid state switching arrangement S which has a control input 41 for controlling the commutation and hence whether electrical power is absorbed or generated.

In the embodiment of Figure 2, the circuit includes a further turbine 20 on the distal side of the electric motor/generator 4 which is connected via a one way clutch 5 to the compressor 1. The conduit 21 for the further turbine 20 is connected to the output side of the main turbine. The clutches are disengaged. A director valve 22 is provided at the junction of conduits 21 and 22 and is moveable between positions 22a and 22b.

For the sake of simplicity, the solid state switching arrangement S and the internal combustion engine 40 have been omitted from Figure 2 and the remaining figures, but will be present in this and the subsequently described embodiments.

Figure 3A shows the mode of operation of the Figure 2 circuit for normal turbo-charging operation in which the clutches are disengaged, air is supplied to the compressor and exhaust gases to the turbine.

In Figure 3B, at start up, air is supplied by the compressor which is driven by the motor which is supplied with electricity. (in some cases this will start the internal combustion engine without recourse to a starter motor).

In Figure 3C, for boosted low speed electrical generation, the clutch 5 is disengaged, air is supplied to the compressor and extra energy is supplied to the turbines by diverting extra energy into the exhaust by late valve timing of fuel and diverted air injection

In Figure 3D, for extra main engine boost, usually during transient conditions, electrical energy is supplied to motor 4 to speed up the turbocharger. The clutch 5 is engaged.

In Figure 3E, for use as a gas turbine auxiliary power unit, the clutch 5 is disengaged; incoming air is diverted to the combustion chamber 7 and the exhaust gases power both turbines.

In Figure 3F, for use as a compound engine for steady state main engine boost, valve 9 is in position c sharing the incoming air between the auxiliary combustion chamber 7 and the main internal combustion engine 40(not shown). Valve 12 is in position c allowing the gases from both the main internal combustion engine 40 and the auxiliary combustion chamber 7 to impinge upon turbine 2.

In all cases the exhaust diverter valves 12a, 12b and 22 may be omitted for simplicity with some performance loss.

By virtue of the structure and modes of operation an engine of the invention can play the following roles:

1. As a gas turbine auxiliary power unit and combined heat and power unit when the main engine is not in operation.

2. As a precharger to assist or achieve start up of the main engine.

3. As a transient booster by electrically speeding up the compressor.

4. As a generator with extra capacity capability at low main engine speeds.

5. As a device for eliminating turbo lag by accelerating the compressor electrically.

6. As a conventional turbo charger.

7. As a compound engine to boost the steady state power of the main reciprocating engine.

The embodiment of Figure 4 is for the principal purpose of increasing the power output of the main internal combustion engine and would be run for considerable periods as a compound engine.

The circuit shown in Figure 4 comprises turbocharger T1 comprising a compressor 2

connected to a turbine 1. A conduit 11 supplies pressurised air from the turbocharger Tl to the cylinders of an internal combustion engine (not shown). Exhaust gas from the engine is passed via a conduit 8 to the compressor 2 of the turbocharger Tl. The conduit 8 has a branch conduit 42 incorporating a valve 25a which is a waste gate diverting excess exhaust gases into conduit 13.

According to the invention, a supplementary turbine set T2 is present. The turbine set comprises a compressor 30 and turbine 20, connected by a shaft 3 to a motor or alternator 4 via clutch device 5. The alternator/motor 4 can be electronically controlled to extract or supply electrical power at the command of an electronic control unit integrated with the main engine control. In this preferred embodiment a supplementary turbocharger T3 is also present. The output from the compressor 20 of supplementary turbine set T2 leads to a combustion chamber 7 including a fuel injection nozzle 14. The output of the combustion chamber leads via a conduit 10 into the exhaust inlet conduit 8 via a regulable control valve 12d and exhaust inlet conduit 13 via a regulable control valve 25. The outlet side of the turbocharger T3 is connected via conduit 28 to the inlet of turbocharger T1, thereby raising the pressure in the main engine inlet manifold conduit 11 to a significantly higher pressure than could be achieved using Turbocharger T1 alone. Extra fuel can then be burnt in the main engine thereby greatly increasing the power developed at the crankshaft. Waste gate control valve 26 is used to control the pressure in inlet conduits 11 and 28. In applications where the engine runs in near steady state conditions waste gates 25 and 26 may not be required.

It is known that by particular control of the flow of the exhaust gases from auxiliary combustion chamber 7 into conduits 8 and 13 that the pressure and temperature regimes in the internal combustion engine 40 can be closely controlled to achieve the maximum power output that the main engine can deliver within the physical constraints imposed by its construction materials.

Alternator/motor 4 can be used to reduce turbo lag by speeding up turbine set T2 by drawing electricity from the batteries

By closure of regulable valves 12d and 25 Turbine set T2 and combustion chamber 7 can drive alternator 4 as an independent Auxiliary power unit.

The system can be operated with a single stage turbocharger system when turbocharger T1 only would be present and the exhaust gases from combustion chamber 7 would be directed into conduit 8 via regulable valve 12d. Regulable valve 25 would be omitted.

The maximum power available for the purpose of boosting the performance of the main engine, is equal to that which would normally be absorbed by generator 4, which would be generating little or even no power when the main engine required maximum boost. Any intermediate stage can provide a combination of boost power and electrical generation down to the point when both regulable valves 12d and 25 are closed and the system operates as a stand alone auxiliary power unit.

In the embodiment of Figure 4a the system is simplified to allow the exhaust gases from combustion chamber 7 to enter only ahead of the primary turbocharger turbine 2. Such a system would also apply to a single stage device. In Figure 4c regulable valve 12d is closed and the system is operating as a stand alone auxiliary power unit.

In the embodiment 4b both turbocharger turbines 2 and 23 are subjected to the same inlet pressure and both turbochargers exhaust to atmosphere. This system lowers the back-pressure in the system and improves efficiency and power output but does not have the flexibility of the system described in Figure 4. In Figure 4d regulable valve 12d is closed and the system is operating as a stand alone auxiliary power unit.

In the embodiment 4e the system is further simplified by introducing the exhaust gases from combustion chamber 7 into conduit 13 via regulable valve 25. This system is relatively easily designed into an existing system but lacks the flexibility of the system described in Figure 4, Figure 4f shows system 4e operating as a stand alone auxiliary power unit.

All embodiments 4,4a,4b,4e will pressurise the main engine manifold prior to start up by being started before the main engine. The main engine can thus run with much lower compression ratios than would otherwise be possible and hence at much higher power outputs. The use of electrical power applied through motor/generator 7 when running as a motor can be used to offset the effects of turbo-lag as in the embodiments of Figures 1 to 3.

In some embodiments of the invention the auxiliary combustion chamber can be dispensed with, and in particular, in accordance with a further aspect of the invention there is provided an internal combustion engine arrangement having a turbocharger comprising a turbine arrangement to drive a compressor and a rotary dynamoelectric machine coupled to the turbocharger via a clutch device the rotary dynamoelectric machine being operable as a generator.

The invention also extends to every novel combination or sub-combination disclosed herein.

CLAIMS.

1. An internal combustion engine arrangement having a turbocharger comprising a turbine (2) arranged to drive a compressor (1), characterised by an auxiliary combustion chamber (7) and which is included in the turbocharger circuit (7, 8, 10, 11).

2. An internal combustion engine arrangement according to claim 1, further comprising a rotary dynamoelectric machine (4) coupled to the turbocharger (1, 2).

3. An internal combustion arrangement according to claim 2 wherein the dynamoelectric machine (4) is operable as a generator and the turbocharger (1, 2) is connected thereto via a clutch device (5).

4. An internal combustion engine arrangement according to claim 2 wherein supplementary means (20) are provided to drive the dynamoelectric machine (4).

5. An internal combustion engine arrangement according to claim 4 wherein said supplementary means is a further turbine (20) arranged to operate in free turbine mode.

6. An internal combustion engine arrangement according to claim 4 or claim 5 wherein said supplementary means (20) is connected to said dynamoelectric machine (4) via a clutch device (5).

7. An internal combustion engine arrangement according to claim 5 or claim 6 wherein an outlet conduit (21) of said further turbine (20) is thermally coupled to a heat exchanger which is arranged to extract heat from its exhaust gases.

8. An internal combustion engine arrangement according to any of claims 2 to 6 wherein said dynamoelectric machine (4) is a high speed, low inertia machine arranged to be driven by the turbocharger (1, 2) at the same rotational speed as the turbocharger.

9. An internal combustion engine arrangement according to any preceding claim wherein said dynamoelectric machine (4) is an A.C. machine and is provided with gate-controlled semiconductor switching means (5) for controlling its generator.

10. An internal combustion arrangement according to any preceding claim wherein a supplementary turbine set (T3) is included in the circuit of said first - mentioned turbocharger (T1) and /or said auxiliary combustion chamber (7).

11. An internal combustion engine arrangement according to claim 10 wherein an output (28) of the circuit of said supplementary turbine set (T3) is arranged to supply pressurised air to the input side of said first - mentioned turbocharger (T1).

12. An internal combustion engine arrangement according to claim 10 or claim 11 wherein said auxiliary combustion chamber (7) is included in the circuit of a further turbine set (T2) and the circuit of said third turbine set has an output which is connected to an input (13) of said supplementary turbine set and/or is connected to the exhaust of said internal combustion engine.

13. An internal combustion engine arrangement according to claim 12 wherein valve means (12d, 25) are provided for controlling the relative gas flows from said output of the circuit of said further turbine set (T2) to the inputs of said main turbocharger (T1) and supplementary turbine set (T3).

14. An internal combustion engine arrangement according to claim 12 or claim 13 as dependent on claim 2 wherein said dynamoelectric machine (4) is coupled to said further turbine set (T2).

15. An internal combustion engine arrangement according to claim 10 wherein said auxiliary combustion chamber (7) is included in the circuit of further turbine set (T2) and an output of the circuit of said further turbine set and an exhaust of a main turbocharger (T1) whose turbine is connected to an exhaust of said internal combustion engine are connected to an input (13) of said supplementary turbine set (T3).

16. An internal combustion engine arrangement according to claim 15 wherein a valve (25) is connected between said output of the circuit of said further turbine set (T2) and said input of said supplementary turbine set (T3).

17. An internal combustion engine arrangement according to Claim 15 or Claim 16 as dependent on Claim 2 wherein said dynamoelectric machine (4) is coupled to said further turbine set (T2).

Patents Act 1977
Examiner's report to the Controller under Section 17
(The Search report)

Application number
GB 9517479.3

Relevant Technical Fields

(i) UK Cl (Ed.N) F1B

(ii) Int Cl (Ed.6) F02B 37/04, 37/12, 37/14

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Search Examiner
R J DENNIS

Date of completion of Search
16 OCTOBER 1995

Documents considered relevant following a search in respect of Claims :-
1 TO 17

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X, Y	GB 2003226 A	(THE SECRETARY)	X: 1 Y: 2 and 3 at least
Y	EP 0367406 A2	(ISUZU)	2 at least
Y	US 4680933	(SIEMENS)	2 and 3 at least
X, Y	US 4389846	(MOTOR-UND)	X: 1 Y: 2 and 3 at least
X, Y	US 4160365	(TSENTRAINY)	X: 1 Y: 2 and 3 at least
X, Y	US 3961199	(ORMAT)	X: 1 and 2 Y: 2 and 3 at least

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